ONTARIO
DEPARTMENT OF MINES

RECENT GEOLOGICAL INVESTIGATIONS IN THE ELLIOT LAKE – BLIND RIVER URANIUM AREA, ONTARIO

by

JAMES A. ROBERTSON

Miscellaneous
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ABSTRACT

This paper is a result of a continuing investigation, begun in 1953, by government geologists and mining companies. The Archean rocks are Keewatin greenstones intruded by Algoman granites for which the geological age has been determined as about 2,500 million years. These granitic rocks consist of gneissic granodiorites and massive, slightly radioactive quartz monzonite. The Archean complex was eroded to a peneplain with valleys in the less resistant rock types. The Lower Huronian consists of the Lower Mississagi Formation, the Middle Mississagi Formation, the Upper Mississagi Formation, the Bruce Conglomerate, the Espanola Formation, and the Serpent Formation. These formations contain a great variety of sedimentary rocks such as conglomerate, argillite, siltstone, greywacke, limestone, and quartzite. Thickness and facies changes indicate a northwesterly source, northerly overlap, and deposition in shallow water controlled by basement topography. The Lower Huronian formations unconformably overlie the Archean rocks and in turn are unconformably overlain by the Middle Huronian formations. The Middle Huronian rocks consist of the Gowganda and Lorrain Formations of conglomerate, greywacke, quartzite, and arkose. There were at least three phases of post-Huronian igneous activity represented by: (1) dikes and sills of Nipissing diabase; (2) the Cutler granite; and (3) dikes of olivine diabase.

Copper mineralization is associated with the Nipissing diabase. Uranium ores in quartz-pebble conglomerates, near the base of the Lower Mississagi Formation, are generally considered

to be placer deposits modified by later events. Uranium production from the Blind River mining camp to the end of 1965 was 122,285,022 lbs. U_3O_8 valued at $1,161,211,459. This was derived from 53,810,070 tons of ore grading approximately 0.1 percent U_3O_8.

Detailed or semi-detailed mapping now covers the greater part of the North Shore of Lake Huron. Regional stratigraphic correlation is now possible but uniform nomenclature and measured type-sections are needed. Commercial radioactive deposits have been found in quartz-pebble conglomerates, the distribution of which was controlled by basement topography and the flow of transporting currents from favourable source areas. Airborne surveys have given useful data in the past, but, even with improved instrumentation, are unlikely to reveal buried deposits. Other possible prospecting techniques applicable to the Huronian area are discussed. Future exploration will be costly.

The Department of Mines will continue its regional mapping program. The continued co-operation of the mining industry is requested during the preparation of a Uranium-Thorium resources inventory.

RECENT GEOLOGICAL INVESTIGATIONS IN THE ELLIOT LAKE - BLIND RIVER URANIUM AREA, ONTARIO[1]

By

James A. Robertson[2]

INTRODUCTION

During the last few years there has been a quiet but steady increase in the interest in uranium and thorium reserves. During 1966 this interest became widespread with the general realization that thermonuclear power was competitive with both hydroelectric power and with conventional thermal power (Bell 1966a,b; Roscoe 1966). The prime purpose of this paper is to make industry aware of the work already carried out by the Department of Mines in the Elliot Lake area; to draw some conclusions from that work; to indicate the course of future work; and, in the printed version, to provide a selected list of references.

Blind River (Fig. 1) is located on the north shore of Lake Huron half way between Sudbury and Sault Ste. Marie. The town of Elliot Lake (Fig. 2) lies 20 miles northeast of Blind River. The area is served by the Canadian Pacific Railway, the Trans-Canada Highway and by other roads.

Semi-detailed mapping was carried out by W. H. Collins in 1915 (Collins 1925). In 1953 uranium was discovered in the district which subsequently became Canada's chief source of uranium. Since 1953 extensive geological work has been carried

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[1] Manuscript received by the Director, Geological Branch, 9 Feb. 1967.

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out by the Ontario Department of Mines, the Geological Survey of Canada, mining companies, and interested individuals. The Ontario Department of Mines has been responsible for regional mapping; this was carried out by E.M. Abraham in 1953-1956 (Abraham 1953; 1957) and has been continued by the writer since 1957 (Robertson, J.A. 1960 et seq). The Geological Survey of Canada was primarily concerned with the geology of the ore deposits. Publications by Roscoe, Roscoe and Steacy, Pienaar, and Lang et al, are standard references (see list of selected references). Since 1960 the Ontario Department of Mines regional mapping program has been continued eastwards from Pronto Mine to Massey. M.J. Frarey and R.E. Hay of the Geological Survey of Canada have carried out semi-detailed mapping in the Iron Bridge-Sault Ste. Marie area (Frarey 1959; 1961a,b; 1962a,b; Hay 1961). Frarey is currently doing similar work in the Lake Panache-Collins Inlet area (Frarey 1965; 1966; 1967). Thomson (1953; 1960), Ginn (1961; 1965) and Card (1965 et seq) have carried out an Ontario Department of Mines mapping program in the counties between Sudbury and Espanola.

Thus the transition from the mere assemblage and presentation of data to the synthesis and analysis of that data is now possible, for example Young and Church (Young 1966a,b; Young and Church 1966) have begun a series of papers on Huronian geology dealing largely with questions of structure and correlation both within and beyond the Huronian sequences mapped in detail. The writer (Robertson 1960) first assembled regional data in 1960 and in 1966 published a paper on the Relationship of Mineralization to Stratigraphy in the Blind River Area, Ontario. Preliminary maps

have been prepared by Giblin and Leahy for the Sault Ste. Marie, and Blind River-Elliot Lake sheets and by Thomson for the Espanola sheet of the compilation series. Fig. 2 shows the areas for which final or preliminary maps are available: The individual maps are listed in the bibliography.

SUMMARY OF GEOLOGICAL DATA

The bedrock of the area falls into three broad units, the distribution of which is shown on Fig. 3. These are: (1) the Archean basement consisting of Algoman granite and Keewatin-type greenstone; (2) the Huronian sedimentary rocks made up of the Bruce Group and the Cobalt Group and (3) the post-Huronian intrusive rocks comprising the Nipissing diabase, the Cutler granite, and olivine diabase believed to be Keweenawan in age (only the Cutler granite is shown in Fig. 3).

The structure is also illustrated on Fig. 3. In the north is the Quirke syncline and in the south the Chiblow anticline, the south limb of which is repeated by a major east-striking fault - the Murray Fault. The axes of these folds strike slightly north of west and plunge gently west giving the sedimentary units a reverse-S shaped outcrop. To the south of the Murray Fault the folding is more intense and complex. In this area fold axes and other linear features generally plunge eastwards. Only the most clearly defined folds are shown on Fig. 3. The La Cloche Hills are defined by Lorrain quartzite forming the core of the La Cloche syncline. Bedding-plane slips, thrust faults, and

near-vertical faults which strike either northwest or parallel to the axial planes of the folds are common. The fault pattern, jointing, dragfolds, and other structural features suggest a north-south compression formed the folds. Several periods of intensity are probable.

Fig. 4 is a Table of Formations giving more detail than it is possible to show on Fig. 3. It has been Ontario Department of Mines policy to retain Collins' nomenclature making modifications only where necessary. S.M. Roscoe (1957) and P.J. Pienaar (1963) of the Geological Survey of Canada have introduced a nomenclature using local names. The differences are in names rather than in concepts (see Fig. 6).

The Keewatin-type rocks underlie the eastern portion of the Quirke syncline and are exposed to the southeast of the syncline. The rock-types found include massive and pillow lavas, pyroclastic rocks, and sedimentary rocks including lean iron formation. Strike is northwest and dips generally steep northeast. Metamorphism is of chlorite grade rising to amphibolite in hybrid zones close to contacts with the Algoman granite.

Granitic rocks of Algoman age (2,500 million years: Lowdon 1960 et seq; Van Schmus 1965) form approximately half the area shown on Fig. 3. These granitic rocks may be divided into two broad groups: (1) medium- to coarse-grained, gneissic to massive granodiorite, generally grey to pink in colour with abundant inclusions of Keewatin-type rocks, and (2) massive red quartz monzonite generally without inclusions and slightly

radioactive. A body of the second type is found in the Quirke Lake area (Fig. 8).

The Huronian sedimentary rocks lie unconformably on the Algoman-Keewatin complex. A topographic low was developed over the greenstone belt, with local ridges controlled by the harder members (Fig. 7). Remnants of pre-Huronian soils are preserved particularly over the granitic rocks. The present chemical constitution of these soils suggests that they were formed under reducing conditions, but not necessarily under a reducing atmosphere.

The Lower Mississagi Formation contains the known workable uranium deposits and has been studied in detail. The general sequence consists of greenish arkose with or without uraniferous quartz-pebble conglomerate beds followed by grey quartzite; followed near Elliot Lake by argillite and impure quartzite. Cross-bedding and pebble orientation studies by McDowell (1957; 1963) and Pienaar (1963) indicate the currents flowed from the northwest but were markedly influenced by basement topography. Ore-conglomerates occur largely in valleys in the basement surface (Fig. 7). Thickness of the Lower Mississagi Formation increases from 0 at the north shore of Quirke Lake through 600 feet near Elliot Lake to more than 1,000 feet near the Murray Fault. As northward overlap is pronounced (Fig. 5) ore-beds at Pronto, Nordic, and Quirke are progressively younger.

The argillaceous section found at the top of the Lower Mississagi Formation increases in thickness to the southeast (Fig. 5) and forms the most important member of the formation as

exposed on the south limb of the Chiblow anticline north of the Murray Fault between Shedden township and the east limit of mapping (Robertson 1965b; 1966b,c). Within the area mapped this unit, but no underlying arkose nor Archean basement, is repeated south of the Murray Fault. Near the fault, it is represented by schists of the almandine staurolite grade but further south by poorly exposed less metamorphosed rocks. The unit south of the fault was formerly called the McKim Greywacke.

Associated with the metamorphic rocks adjacent to the Murray Fault and apparently the oldest exposed unit in the vicinity of Spragge (Robertson 1966d) and again in Shedden and Victoria townships (Robertson 1966b,c) is a series of massive to schistose mafic rocks, probably of volcanic origin. These are similar to the Thessalon and Duncan greenstones mapped by Frarey (1961b; 1962) and placed by him in the Lower Huronian. Knight and Fairbairn (1966) have recently released preliminary results of age-dating studies on volcanic rocks of the North Shore of Lake Huron. They obtained Rb-Sr isochron ages of about 2,000 m.y. for both the Thessalon volcanics and "Sudbury Series" sediments, 2,496 $\pm$ 145 m.y. for the volcanics at Pater Mine and Shedden township, and 2,215 $\pm$ 185 m.y. for an inclusion in the Algoman granites. These results are inconsistent with the ages accepted for the Nipissing diabase (2,155 m.y.) and for the Algoman granites (2,500 m.y.). In areas of considerable intrusive activity at 2,155 m.y. and of complex structural history it is questionable whether the concept of a stable closed Rb-Sr system is valid. Further detailed age-determination work, including lead-

lead determinations on zircon, carried out in conjunction with detailed geological mapping and petrographic studies is required before the absolute geological time scale in the Lake Huron area can be regarded as fully established. No volcanic rocks have been identified in the Huronian of the Blind River and Elliot Lake areas. In Victoria and Salter townships (Robertson 1966b,c) mafic volcanic rocks are believed to lie on the Algoman granite and either to pre-date the deposition of the Lower Mississagi Formation or to be intercalated with the lowermost members of that formation. (On Fig. 3 these rocks have been indicated by broken diagonal shading.) These rocks extend eastwards into May township where radioactive mineralization is associated with intercalated conglomeratic quartzites. Radioactive conglomerates of Blind River type occur locally in the Thessalon and Duncan greenstone assemblages (Frarey 1961b; 1962; Giblin and Leahy 1965a,b).

The Middle Mississagi Formation in the Quirke syncline consists of a basal polymictic conglomerate followed by argillite. The Conglomerate was used as a marker horizon during exploration drilling. The argillite thickens from less than 100 feet at the north shore of Quirke Lake to over 750 feet near Elliot Lake (Fig. 5). Near the crest of the Chiblow anticline the conglomerate is about 5 feet thick and the argillite only 40 feet but on the south limb of the Chiblow anticline, both north and south of the Murray Fault, in the vicinity of Blind River and Algoma Mills the Middle Mississagi is represented by 800 feet of quartzite and siltstone. However, in Shedden and Victoria townships a conglomerate

is found occupying a similar stratigraphic position in the Huronian exposed north of the Murray Fault (see Fig. 5). South of the Murray Fault, running eastwards from the Spanish River estuary the Ramsay Lake conglomerate, considered by Collins to be the base of the Huronian, may be the continuation of both the conglomerate sheets referred to above (Robertson 1965d; 1966b,c).

The Upper Mississagi Formation consists of greenish arkose on the north limb of the Quirke syncline but elsewhere of well-bedded grey quartzite. Thickness ranges from 600 feet at Quirke Lake to 1,500 feet near Elliot Lake and to a maximum of 2,700 feet on the south limb of the Chiblow anticline, as exposed both north and south of the Murray Fault at Blind River. Current direction was from the northwest but the influence of basement topography was much diminished.

On the south limb of the Chiblow anticline between Lewis township and the east limit of mapping the Upper Mississagi consists of some 3,000 feet (Fig. 5) of well-bedded, cross-bedded feldspathic quartzites with occasional beds of conglomeratic intraformational breccia or polymictic conglomerate, both of which are locally slightly radioactive. To the south of the Murray Fault the Upper Mississagi Formation forms the line of rugged islands between John and Eagle Islands and is also present on I. R. 5. Apart from the immediate Blind River-Elliot Lake area the Mississagi Formation as mapped by Collins (1925) is equivalent to only the Upper Mississagi Formation of the writer (Fig. 6). Those looking south of the Murray Fault for uranium at the base of

rocks mapped by Collins as Mississagi have probably been looking at too high a horizon. It should be noted that the favourable arkosic member of the Lower Mississagi, if present, does not outcrop (Robertson 1965b,c,d; 1966b,c).

The Upper Mississagi Formation is followed disconformably by the Bruce Conglomerate - which consists of boulders of white granite and greenstone in a partially sorted, slightly pyritic, siliceous greywacke matrix. The conglomerate can be traced throughout the entire district. There are marked local variations in thickness but the unit is generally less than 200 feet thick (Fig. 5).

The Espanola Formation consists of three units, all of which are mappable within the Elliot Lake district; (Fig. 5) a lower unit, characterized by limestone - the Bruce Limestone; a middle unit, characterized by mudstone and greywacke - the Espanola Greywacke; and an upper unit having a marked development of ferruginous dolomite - the Espanola Limestone. This three-fold subdivision is not possible in the southeastern part of the area mapped and both north and south of the Murray Fault the formation has not been subdivided (Robertson 1965c,d; 1966b). Throughout much of the western and southern parts of the map-area the Cobalt Group rests unconformably on the Espanola Formation

The Bruce Limestone consists of thinly interbedded cream-coloured limestone and siltstone. Differential weathering and drag-folding give the rock a spectacular appearance. Where the unit is complete, the thickness is generally 100 feet.

The Espanola Greywacke and Espanola Limestone members can only be distinguished by the brown-weathering dolomite bands.

Both members are characterized by intraformational breccias, siltstone and conglomerate dikes, mud cracks, and ripple marks. These indicate shallow water deposition and tectonic disturbance. Occasional quartzite beds, which become more common to the northwest show crossbedding indicative of northwesterly derivation. Where complete the thickness of the Espanola Greywacke is 300-400 feet and that of the Espanola Limestone 150 feet.

The Espanola Formation as exposed in Victoria township comprises siltstone and impure quartzite with carbonate beds poorly developed. Radioactivity has been recorded (Robertson 1966b, Ont. Dept. Mines assessment files). This is apparently associated with the more siliceous beds. To the south of Aird Island (Robertson 1965d) the Espanola Formation contains strongly cross-bedded, feldspathic quartzites, as well as argillaceous and carbonate-bearing beds showing excellent shallow water, current, and slumpage structures.

The Espanola Formation is overlain by the Serpent Formation - a white feldspathic quartzite best exposed in the northern and eastern sections of the Quirke syncline. The maximum known thickness of the Serpent Formation is 1,100 feet. Crossbedding, and lithology and thickness changes in individual members again show derivation from the northwest. Ripple marks and mud cracks indicate shallow water conditions. The unit is also exposed in Shedden township north of Walford Lake and on islands in the north channel of Lake Huron at the south limit of the area mapped (Robertson 1965b,c,d).

The lateral variation in thickness of the formations of the Bruce Group is illustrated in Fig. 5.

The Bruce Group is followed unconformably by the Cobalt Group which, in the Blind River-Elliot Lake area, consists of the Gowganda Formation and the Lorrain Formation. Within the map-area the Gowganda Formation rests on all formations between the Upper Mississagi and the Serpent Formation. Locally the contact can be seen truncating the bedding of the underlying formations and consolidated fragments of the underlying rocks are found in the lowermost beds of the Gowganda Formation.

The Gowganda Formation is a heterogeneous assemblage of conglomerate, greywacke, quartzite, and argillite. These rock types are found throughout the sequence though the lower part is characterized by boulder conglomerate and the upper by quartzite and argillite. Within the area mapped the Gowganda Formation is about 2,000 feet thick.

The origin of the Gowganda Formation is in doubt. Dense boulder conglomerates, quartzites, and argillites were definitely water laid; varved conglomerates and greywackes probably formed under conditions characterized by alternate freezing and thawing although some authorities would ascribe these rocks to turbidity currents; and sparse boulder conglomerates with disrupted greywacke matrix may be either tillites or mudflow deposits. Ovenshine (1964; 1965) has recently described the structures of the Gowganda Formation of the Elliot Lake-Blind River area and has endorsed a glacial environment.

Locally in the Quirke syncline the Gowganda Formation is overlain by a few hundred feet of well-stratified, crossbedded, arkosic quartzite tentatively correlated with the basal Lorrain.

Following Huronian times the region was subjected to tectonic stress. The folding and faulting (briefly summarized earlier) and the intrusion of the post-Huronian diabase took place. The post-Huronian diabase is divided into two phases: the earlier or Nipissing diabase comprises large irregular sill-like gabbro bodies and the later numerous vertical dikes striking either northwest or west. The gabbroic bodies, the distribution of which shows marked structural control, are differentiated from gabbro to diorite and, in some cases, to granophyre. The copper deposits of the district are related spatially and probably genetically to these gabbroic bodies. Alteration (albitization, chloritization, and carbonatization) associated with either dikes or sills have locally affected the uranium deposits. According to Van Schmus (Van Schmus 1965) the gabbroic bodies have a probable age of 2,155 $\pm$ 80 million years.

The only granite of probable post-Huronian age is the Cutler Batholith to the south of Spragge. Age determinations, obtained by Fairbairn et al (1960), Wetherill (1960), and the Geological Survey of Canada (Lowdon 1961 et seq) range between 1,750 and 1,300 million years and determinations on metamorphic mica in adjacent rocks give 1,400 million years.

There were several periods of post-Huronian deformation - the second and subsequent events are best studied south of the Murray Fault and eastwards towards the Espanola and MacGregor Bay areas (Card 1964 et seq; Young 1966a,b). The earliest of these deformations took place prior to the intrusion of the Nipissing diabase; the second caused a foliation in the diabase which was

converted to epidiorite, hornblende schist, amphibolite, and locally garnetiferous amphibolite, whilst the argillaceous rocks of the Lower and in places the Middle Mississagi formations were converted to mica-staurolite-(cordierite)-garnet-quartz-feldspar schists and the quartzites to schists. Card (1964) has studied the metamorphic rocks and shown that there are nodes of higher grade metamorphism in the Agnew Lake area. One such node may have occurred in the Spragge-Cutler area. This second deformation was followed, probably after no great interval, by a third which introduced a second cleavage almost parallel to the first and further compressed the previous folds causing some deviation of the foliation already present in the epidiorites. The Cutler batholith was intruded after the major visible deformations and metamorphism of the epidiorite and the associated metasedimentary rocks. The distribution of the granite is markedly controlled by the larger sheet-like epidiorite bodies: this is particularly the case at the east end of the batholith which is controlled by a easterly plunging antiform defined by epidiorite (Robertson 1965b,c; 1966b). The petrology and structural relations of the Cutler batholith are being further studied by W. Cannon, graduate student at Syracuse University. The Cutler granite is itself strongly foliated and cataclastic structures have developed subsequent to consolidation. The structural trends associated with this deformation are essentially parallel to those of the earlier deformations. The 1.3 - 1.4 billion year age-determinations may have been caused by regeneration of the micas during this period of tectonic activity. In many areas a late kink banding and an

incipient cleavage in a northerly direction are seen. These features are more common in the Espanola area (K.D. Card, personal communication).

A few olivine diabase dikes strike northwest throughout the district. Van Schmus (1965) has established an age of 1,225 ± 25 million years for an olivine diabase dike which cuts the Cutler granite. Similar olivine diabase dikes found throughout the Lake Huron-Sudbury area give ages of 1,000 - 1,100 million years (Lowdon et al 1963).

The olivine diabase dikes are displaced by the Murray Fault indicating late tectonic disturbance. Horizontal displacement measured on magnetic anomalies associated with olivine diabase dikes is 5,000 feet north side east.

ECONOMIC GEOLOGY

The uranium deposits are found (Figs 5, 7) as quartz-pebble pyritic conglomerate beds in zones controlled by basement topography. In the Quirke syncline the relationship of the uraniferous conglomerates to granite-greenstone contact areas and valleys over softer zones in the greenstone belt is clearly demonstrated (Fig. 7). At Pronto, however, there is no clear relationship to basement geology which raises the possibility that there may be other economic uranium deposits underlain by granite.

The ore-zones strike northwest-southeast and are controlled by basement structures. The Quirke zone (the largest in the area) is 32,000 feet long and from 6,000 to 9,000 feet wide and the Nordic zone is 19,000 feet long and from 4,400 to 6,000 feet

wide (Robertson 1967). The Pronto deposit (Robertson 1966d) and the unworked zones are of smaller dimensions.

The uraniferous quartz-pebble conglomerate and green arkose sequence is characteristic of the Lower Mississagi Formation and has been used by Thomson (1960; 1962) as a marker horizon in tracing the Archean-Huronian boundary between Lake Timagami and Blind River. Locally where overlap brings Upper Mississagi into close proximity with the basement, arkose with thin slightly radioactive pebble bands is found. The uranium-mineralization is thus associated with whichever are the local basal beds of the Huronian sequence.

The conglomerates consist of well-rounded, well-sorted, quartz pebbles in a matrix of quartz, feldspar and sericite and have an average pyrite content of 15 percent. Monazite and zircon are characteristic heavy minerals. Brannerite and uraninite are found in the matrix. Thucholite is found locally and may line fissures in the ore beds. The ore-minerals are brannerite, uraninite, and monazite. Roscoe has shown the uranium-thorium ratio is comparable to that of the basement. The lateral variation in the ore-mineral and uranium-thorium ratios as studied by Roscoe (1959), D. Robertson (1962), and Thorpe (1963) are best explained by the relative stability of monazite during transportation. Locally, individual conglomerate bands may assay as high as 20 lbs. or more U_3O_8 per ton, but over mining widths of the order of 9-30 feet average grade of those beds which are, or have been, mined is 2-3 lbs U_3O_8 per ton.

The arkose interbedded with the ore-conglomerate is generally greenish in colour and is crossbedded.

It is probable that the conglomerate accumulated as placer deposits derived from weathered red-phase Algoman granite and that the uranium-bearing minerals were altered and redistributed during diagenesis, during the different periods of tectonic stress, and definitely during the introduction of diabase. There is no evidence in the area mapped by the writer, of crosscutting uranium mineralization. Alternative theories include: deposition from hydrothermal fluids derived from post-Huronian granite as suggested by Davidson (1957); biogenic precipitation of uranium derived from weathered basement but transported in solution as proposed by Derry (1960); and normal solution during weathering and transportation with the method of re-precipitation not restricted to organisms as suggested by Joubin (1960).

Uranium production from the Blind River mining camp to the end of 1965 was 122,285,022 lbs. U_3O_8 valued at $1,161,211,459. (Ont. Dept. Mines statistics). This was derived from 53,810,070 tons of ore grading approximately 0.1 percent U_3O_8. Although there are large drill-indicated reserved left, (Bell 1966a,b; Roscoe 1965; 1966), these are not sufficient to meet projected demands beyond 1975 or, with price increase to $10-$20/lb. U_3O_8, 1980. By-products include small amounts of thorium and yttrium.

PROSPECTING GUIDES AND METHODS

All commercially significant uranium and thorium deposits, regardless of which mode of origin one believes in, are in sheets of oligomictic conglomerate. These are therefore the primary exploration targets and apparently their distribution is controlled largely by basement topography in turn controlled by basement geology. Having defined the target the real problem is how best and most economically can that target be found.

The unexplored areas are largely those where the favourable Huronian - pre-Huronian contact is covered by several thousand feet of rock. There is probably little chance within the Huronian environment, which has already been mapped and thoroughly prospected, of discovering new deposits of uranium and thorium by the traditional methods of surface mapping and ground or airborne radioactivity surveys. Drilling is the only method by which a deposit can be proved. Roscoe (1965, p.16) has indicated that regional exploration drilling with holes several miles apart would have found the known deposits of the Quirke syncline. Such a grid could have missed a deposit the size of the Pronto orebody. D. Robertson (1961) has provided an excellent review of the problems encountered in deep drilling in the Huronian environment. Careful control of drilling and the use of modern drill surveying techniques are essential. The regional valley structures are expressed by deviations in the Huronian - pre-Huronian contact and by changes in thickness and facies of the mappable rock units (Figs. 3,5,7). Such changes may be visible in units at horizons considerable younger than the uranium-bearing beds. Careful study of drill core throughout the length of the hole and comparison of thickness and lithologies with those in adjacent holes may provide important clues to the possible location of conglomerate-bearing structures.

Drill-hole data should be standardized for use in computer storage and retrieval systems as is being done for the oil and gas wells in Ontario in a program sponsored by the Ontario Department of Energy and Resources Management, the University of Western Ontario, and the Industry (Sharp and Brigham; 1965, p. 242-247). Computers are programmed to draw maps showing structure contours, isopachs, distribution of reefs, etc. and

similar programming could be used to produce computer-maps of basement ridges and valleys to guide the exploration for uranium.

Airborne scintillometer surveys, carried out in the early fifties, reveal much of geological and prospecting interest. In 1952 an aeromagnetic-aeroradioactivity survey was carried out under the auspices of the Ontario Department of Mines of an area to the southwest of the Sudbury irruptive - this includes the Agnew Lake area. Following the discovery of the Blind River uranium deposits Professor Brownell, the pioneer of the airborne scintillometer, carried out airborne prospecting in the Baldwin township and the Blind River Z-structure areas (Brownell and Schaller 1954). They found that in Huronian areas contour flying at heights of less than 400 feet and ground follow up were necessary for the accurate identification of anomalies. In Baldwin township they found anomalies not shown on the O.D.M. 1952 map and did not find all anomalies shown on the earlier map. This may be partly attributed to differences in instrumentation and partly to the flight pattern for the O.D.M. maps being designed for magnetic rather than scintillometer work.

In the Blind River sedimentary belt they defined some 35 anomalies which show a marked relationship to the outcrop of the Lower Mississagi Formation. In general anomalies greater than 2 x lake background coincide with outcrops of uranium-bearing rocks of economic interest. At the east end of the Quirke syncline scattered anomalies are associated with the base of the Gowganda Formation. In Shedden and Victoria townships northeast of the Cutler batholith linear anomalies mark the outcrop of the Upper Mississagi Formation - here arkosic and in Victoria township

containing redioactive breccias and conglomerates (Robertson 1966b).

In 1954 and 1955 the Ontario Department of Mines aeromagnetic-aeroradioactivity surveys were extended to the Algoma and Blind River blocks covering all except the eastern end of the Blind River reverse-S structure.

As with Baldwin township there are differences between the maps published by the Department and that of Brownell and Schaller and these differences should again be attributed to differences in instrumentation and technique. Fig. 8 is a compilation of the published anomalies as shown on the Departmental maps. The following relationships are revealed when the distribution of these anomalies is compared to regional geology:

1. The outcrop area of the arkosic phase of the Lower Mississagi Formation is generally radioactive. This included the outcrop of the ore zones and presumably the anomalies corresponding to the ore-outcrops were more intense than the others (intensity is not shown) - they are certainly larger.
2. The red phase granites in the basement particularly north of Quirke Lake are radioactive.
3. The long axis of the Cutler batholith is defined by anomalies.
4. The outcrop of the Upper Mississagi Formation of Ten Mile Lake is radioactive. In this area the formation is arkosic and there are scattered slightly radioactive pebble bands (Robertson 1963a, p. 21).
5. A zone of anomalies correspond to the Upper Mississagi Formation as exposed on Aird and adjacent islands southeast of the Cutler batholith.

Thus the anomalies on both Departmental maps and that of Brownell and Schaller are restricted to areas of little overburden and to those rocks which are richest in potash feldspar as well as containing assessory or detrital uranium- or thorium-bearing minerals. In the Blind River-Elliot Lake area many of these anomalies were drilled (Robertson 1963a; 1964a) but in many cases no pebble bands or conglomerate beds were found.

Both the Federal Survey (Killeen 1967) and the geophysical instrumentation and exploration companies are developing three-level ratemeters capable of distinguishing U- Th- and K-radiations. A recent paper by Pemberton and Seigel (1966 p. 81-87) outlines development of these instruments particularly for airborne use. However, within the Huronian areas it is probable that the chief use of these instruments will be in the examination of samples, core-logging, and down-the-hole logging (see also Roscoe 1965).

The question of seismic surveys has been raised in many informal discussions. Seismic studies are based on the study of the passage of energy waves as they are refracted or reflected through rocks. Where the physical characteristics of the rock assemblage are such that the energy waves have markedly different velocities in adjacent rocks a maximum of information can be obtained. In the oil and gas industries seismic surveys are much used to obtain information on depth and distribution of marker horizons, leading to structural and isopach studies. Major faults, and intrusive bodies may also be revealed. In view of the obvious analogy to uranium exploration in the Huronian the Geological Survey of Canada have initiated experiments in the Elliot Lake area (Overton 1967, p. 155). Preliminary results indicate that

the rocks of the Huronian sequence and the Archean basement have similar velocities and that therefore the reliable delineation of the pre-Huronian surface by seismic methods is unlikely. Further experimentation and publication of details of methods, results, and costs are required before industry can evaluate the use of seismic studies as an exploration tool.

Studies of airborne magnetic maps either in a qualitative manner as indicated on Fig. 7 or by quantitative analysis as suggested by Steenland and Brod (1960, p. 586-601) may be of use where the basement is known to contain either iron-formation or generally magnetic mafic rocks, but such methods are not likely to predict basement lows developed over granitic areas.

Clearly further uranium or thorium deposits within the Huronian are not going to be found cheaply or easily. More advanced and costly exploration techniques, perhaps similar to those of the oil industry, are going to be developed and used. That the potential prize is great, that the price of uranium within broad limits does not materially affect the competivity of thermonuclear power, that reserves of radioactive fuels are limited (Bell 1966a,b; Roscoe 1965; 1966) should provide the incentive and challenge to the Canadian and American mining industries to continue uranium exploration in the Huronian rocks of the Elliot Lake - Blind River area.

FUTURE ONTARIO DEPARTMENT OF MINES MAPPING

During the coming field season (1967) a field party should complete mapping the area between Spanish River and the North

Channel of Lake Huron. During the succeeding two field seasons the Massey-Webbwood area will be mapped by which time the link up with K.D. Card, now working near Espanola, should be achieved. A number of uranium as well as base metal occurrences are already known in this area, which lies just west of the Agnew Lake area of current exploration interest. Over the same period another party will start mapping in the Rawhide Lake-Mount Lake area to the north of the Quirke syncline. In this area the upper members of the Huronian overlap onto the basement and they are known to contain thorium-uranium mineralization. Following completion of the Webbwood mapping either or both parties will be engaged in systematic detailed mapping of the Huronian outcrops to the west of Mount and Flack lakes.

URANIUM-THORIUM INVENTORY AND DATA PROCESSING

The Geological Branch of the Ontario Department of Mines has recently organized an Information and Education Section. The functions of this section include setting up a card index system for all known mineral deposits in Ontario. This system, which will be eventually linked to a mechanical data-processing system, will be made up as follows: 1) a complete central file located in Toronto; 2) a file maintained in each Resident Geologist's office for the territory assigned to that office. It should be noted that the Blind River-Elliot Lake mining camp is the responsibility of the Sault Ste. Marie resident geologist although much of the camp lies in the Sudbury Mining Division; 3) a set of cards to be maintained by the person or persons responsible for a given metal,

group of metals, or mineral products in question. At present D.F. Hewitt and the writer are responsible for setting up the cards for Uranium-Thorium and for the preparation of Metal Resources Circulars for those metals. Dr. Hewitt (1967) has prepared the circular (MRC. No. 4) for deposits in southern Ontario (i.e. the Grenville Province) and the writer is preparing that for deposits in northern Ontario.

As exploration for new reserves and re-examination of already known occurrences takes place much new data will be rapidly collected. It is hoped that the close co-operation which has existed between the Department's Geological Branch and the uranium mining and exploration companies will be continued. It is also hoped that, within the scope of the security policies of such companies, much of the new information will be voluntarily placed on file with the Department. Data on unsuccessful exploration programs may well be as useful in this respect as that from programs which succeed in finding new ore. The information thus gathered will be available to the entire mining fraternity resulting in less duplication of effort, better delineation of favourable areas, and more effective spending of exploration funds.

ACNOWLEDGMENTS

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FIG. 1 LOCATION OF BLIND RIVER AREA

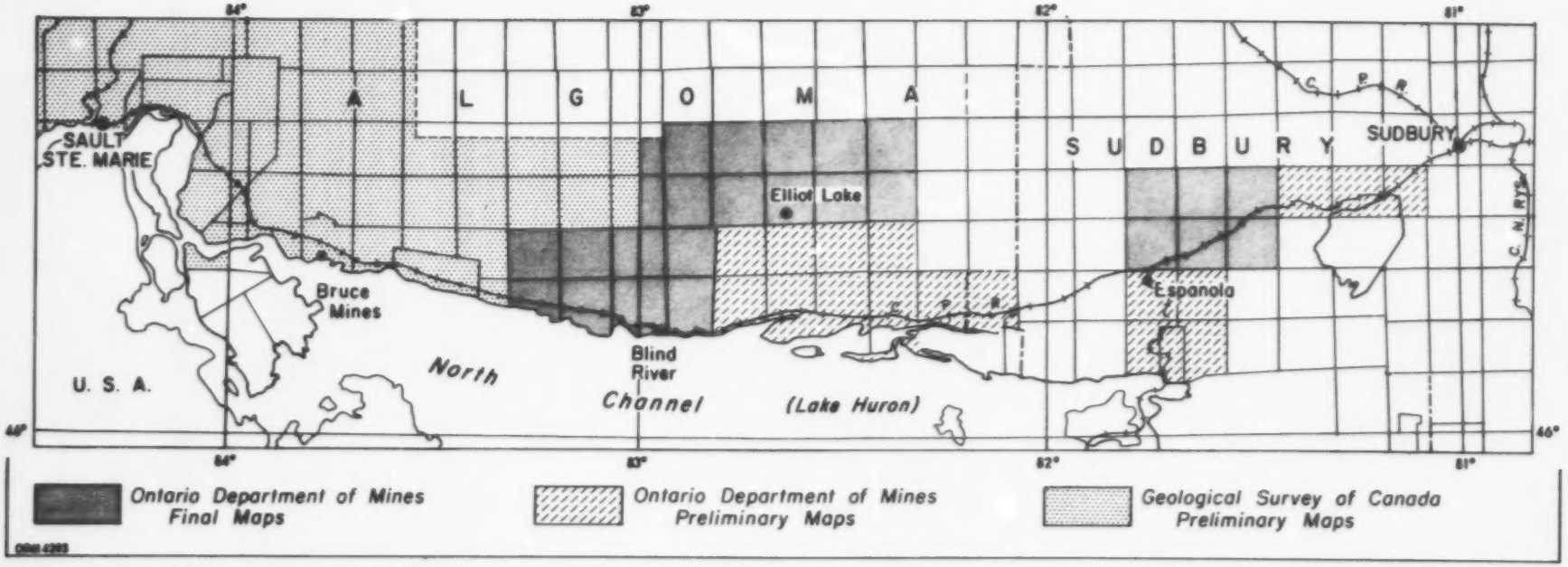
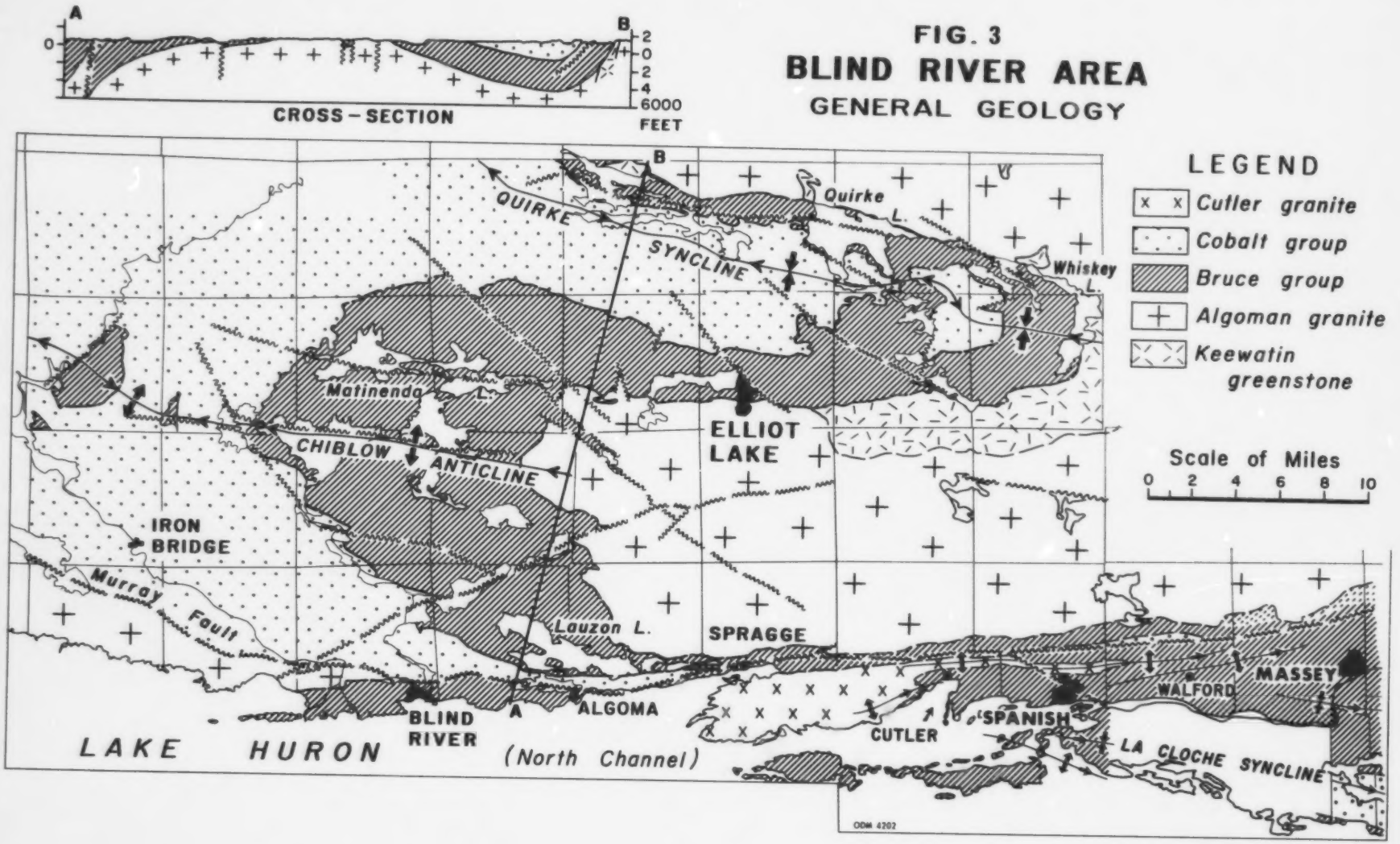


Figure 2– Key to recent geological maps, North Shore of Lake Huron *(Maps listed in Bibliography)*


A
B
0
2
0
2
4
6000
FEET
CROSS – SECTION
FIG. 3
BLIND RIVER AREA
GENERAL GEOLOGY
LEGEND
Cutler granite
Cobalt group
Bruce group
Algoman granite
Keewatin greenstone
Scale of Miles
0 2 4 6 8 10
QUIRKE SYNCLINE
Quirke L.
Whiskey L.
Matinenda L.
CHIBLOW ANTICLINE
ELLIOT LAKE
IRON BRIDGE
Murray Fault
Lauzon L.
SPRAGGE
BLIND RIVER
ALGOMA
CUTLER
SPANISH
WALFORD
MASSEY
LA CLOCHE SYNCLINE
LAKE HURON
(North Channel)
ODM 4202

UNIT	LITHOLOGY	AGE
		MILLION YEARS
CENOZOIC		
RECENT & PLEISTOCENE	*Sand, gravel*	
GREAT UNCONFORMITY		
PRECAMBRIAN		
PROTEROZOIC		
KEWEENAWAN	*Olivine diabase*	1,225
INTRUSIVE		
PENOKEAN	*Granite*	1,750
INTRUSIVE		
NIPISSING	*Quartz diabase*	2,155
INTRUSIVE		
HURONIAN		
COBALT GROUP		
LORRAIN	*Quartzite*	
GOWGANDA	*Conglomerate, greywacke*	
UNCONFORMITY		
BRUCE GROUP		
SERPENT	*Quartzite*	
ESPANOLA	*Limestone, greywacke*	
BRUCE CONGLOMERATE	*Conglomerate*	
UPPER MISSISSAGI	*Quartzite*	
MIDDLE MISSISSAGI	*Argillite* *Conglomerate*	
LOWER MISSISSAGI	*Argillite* *Quartzite, ±U-conglomerate* *Conglomerate* *Arkose + U-conglomerate*	
UNCONFORMITY		
ARCHEAN		
ALGOMAN	*Granite*	2,500
INTRUSIVE		
KEEWATIN	*Volcanic and sedimentary rocks*	

FIG. 4 TABLE OF FORMATIONS

Figure 5 – Lateral Variation in Bruce Group

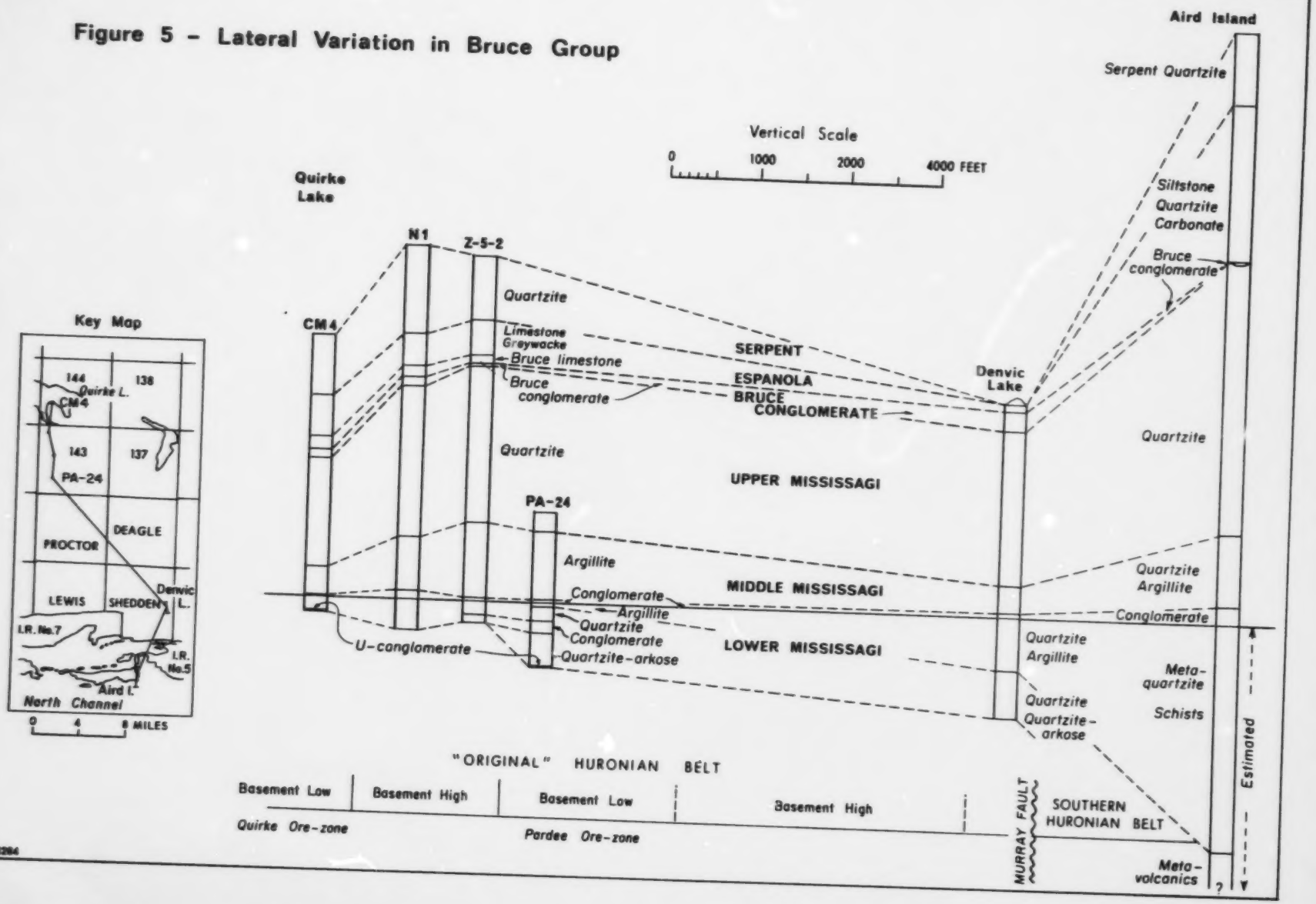


FIG. 6 : COMPARISON OF STRATIGRAPHICAL NOMENCLATURES USED FOR NORTH SHORE OF LAKE HURON.

Logan & Murray 1863	Coleman 1914	Collins 1925	Abraham 1953, 1957	Roscoe 1956 as in Pienaar 1963	Robertson 1965 North of Murray Fault	Robertson 1965 South of Murray Fault	Collins etc. South of Murray Fault	Rock - Types
Greenstone Intrusions	Intrusions	Keweenawan: Olivine Diabase; Granite; Diabase, incl. Thessalon Greenstone	Keweenawan: Olivine Diabase; Granite; Diabase	Keweenawan: Olivine Diabase; Granite; Diabase	Keweenawan; Nipissing	Keweenawan; Cutler Granite; Nipissing	Keweenawan: Olivine Diabase; Granite; Diabase	Olivine Diabase; Granite; Diabase Dikes; Gabbro Sills
Upper Formations	Upper Huronian	Cobalt G: Upper Formations; Gowganda	Cobalt G: Upper Formations; Gowganda	Cobalt G: Upper Formations; Gowganda	Cobalt G: Upper Formations; Gowganda	Cobalt G: Not present in area mapped.	Cobalt G: Upper Formations; Gowganda	Quartzites; Conglomerate, Quartzite
Upper Slate Conglomerate	Lower Huronian	Bruce Series: Serpent; Espanola; Bruce Limestone; Bruce Conglomerate; Mississagi	Bruce Group: Serpent; Espanola; Bruce Limestone; Bruce Conglomerate; Upper Mississagi; Middle Mississagi; Lower Mississagi	Quirke G: Serpent; Espanola; Bruce Limestone; Bruce Conglomerate; Hough Group: Mississagi; Pecors; Whiskey; Elliot Group: Nordic; Matinenda (Upper); Matinenda (Lower)	Bruce Group: Serpent; Espanola; Bruce Limestone; Bruce Conglomerate; Upper Mississagi; Middle Mississagi; Lower Mississagi	Bruce Group: Serpent; Espanola; Bruce Conglomerate; Upper Mississagi; Middle Mississagi; Middle Mississagi; Lower Mississagi; Spragge Group: Peter Volcanics; ?	Bruce Series: Serpent; Espanola; Bruce Conglomerate; Mississagi; Ramsay Lake	Quartzites; Dolomite, Siltstone Limestone; Conglomerate; Quartzite; Argillite ± Quartzite → Schists; Conglomerate → Schists
Limestone								
Lower Slate Conglomerate								
White Quartzite								
Chloritic Slates							Sudbury Series: McKim; Wanapitei	Argillite ± Quartzite → Schists; Andesite → Meta-And.; Quartzite; Quartzite - Arkose ± U - Conglomerate
Grey Quartzite								
Laurentian Granite	Laurentian Granite	Algoman Granite	Algoman Granite	Algoman Granite	Algoman Granite			
	Sudbury Series	Sudbury Series	Keewatin	Greenstone	Keewatin		Schist Complex (Kéwatin)	Granite etc.; Sediments; Volcanics
	Granite Keewatin	Schist Complex						

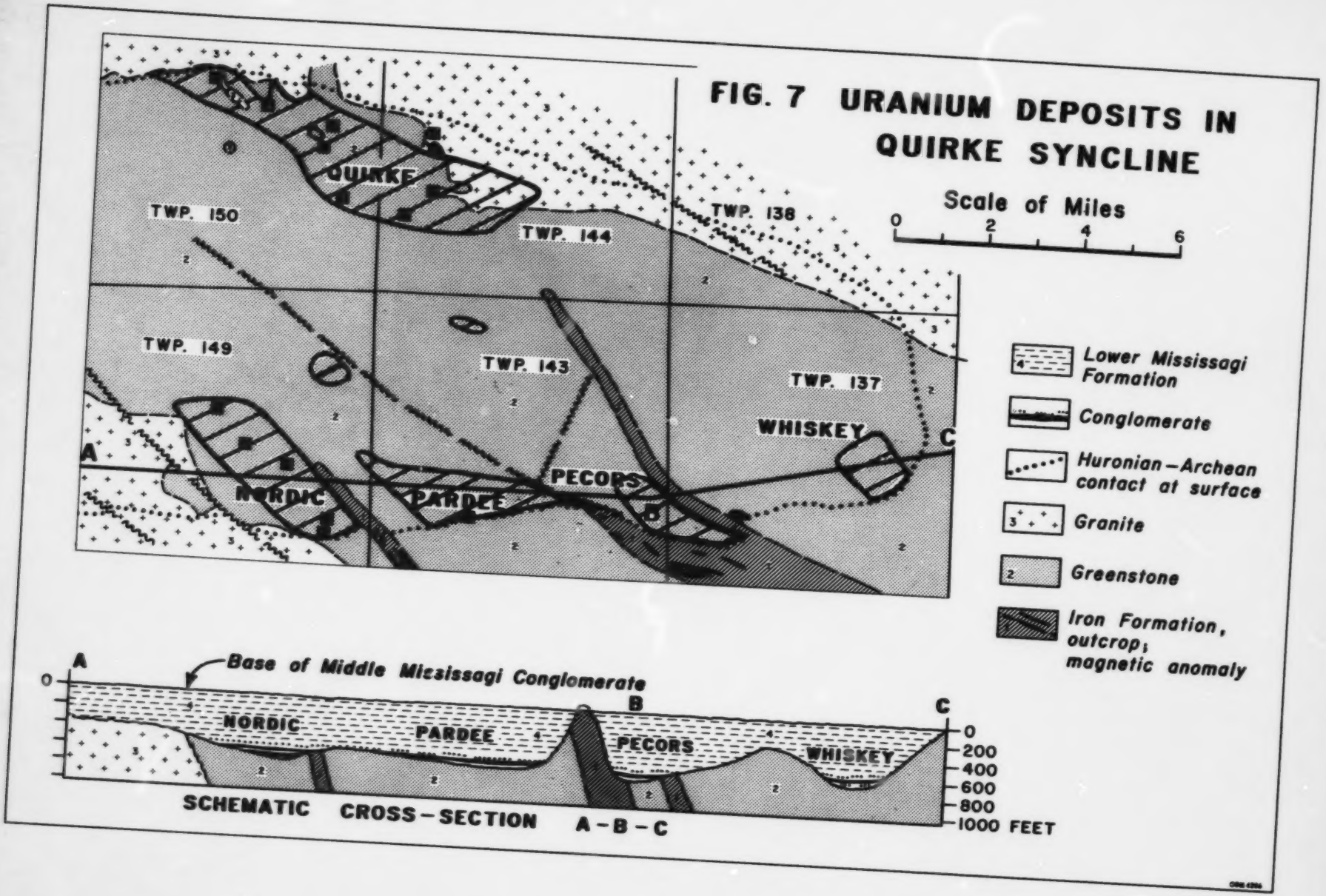


FIG. 7 URANIUM DEPOSITS IN QUIRKE SYNCLINE
Scale of Miles
0 2 4 6
QUIRKE
TWP. 150
TWP. 144
TWP. 138
TWP. 149
TWP. 143
TWP. 137
WHISKEY
A
C
NORDIC
PARDEE
PECORS
Lower Mississagi Formation
Conglomerate
Huronian–Archean contact at surface
Granite
Greenstone
Iron Formation, outcrop; magnetic anomaly
A
Base of Middle Mississagi Conglomerate
B
C
0
NORDIC
PARDEE
PECORS
WHISKEY
0
200
400
600
800
1000 FEET
SCHEMATIC CROSS–SECTION A–B–C

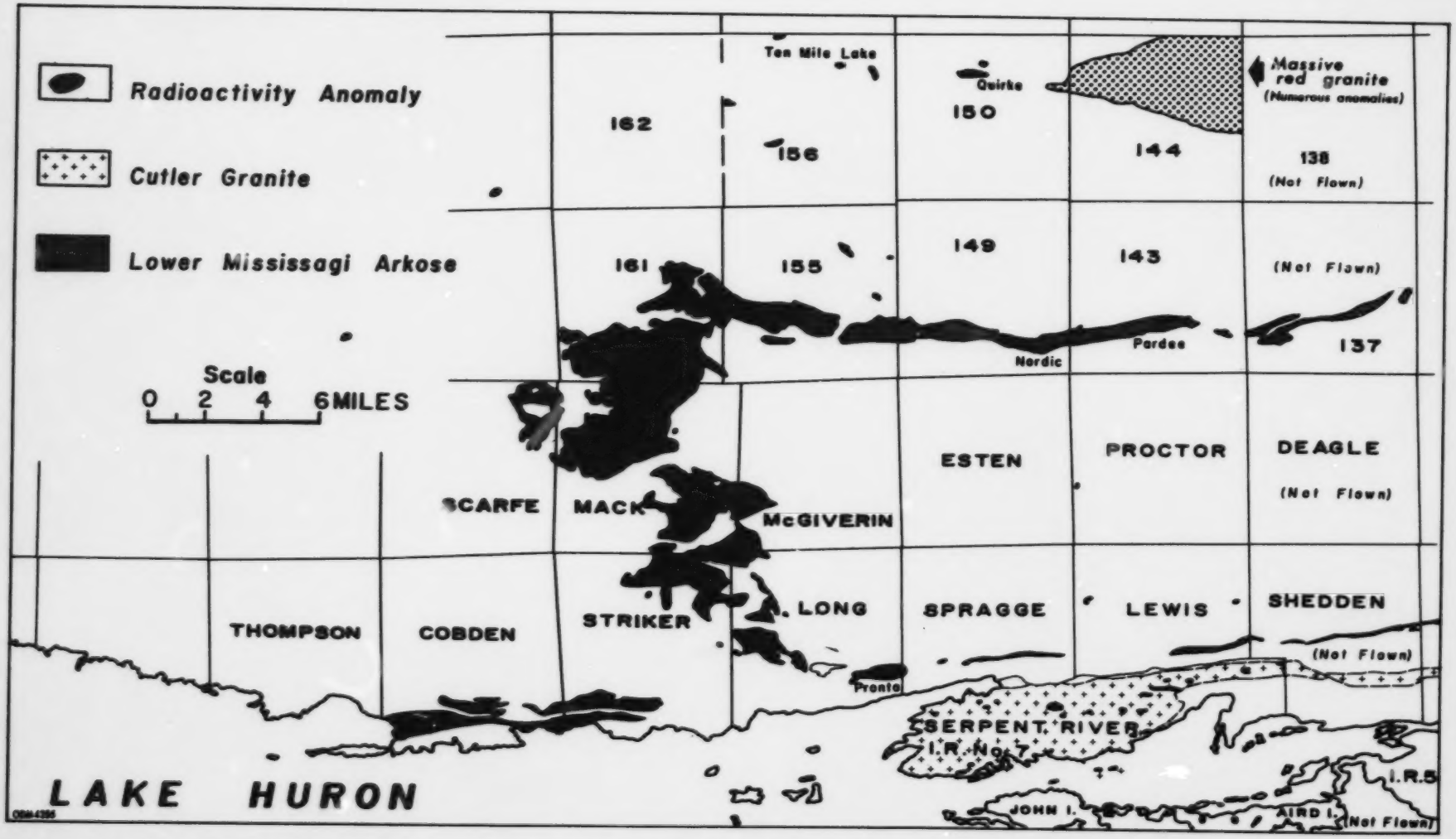


FIG. 8 DISTRIBUTION OF AERO-RADIOACTIVITY ANOMALIES, BLIND RIVER AREA.